Mesh evaluation

The estimation of the spacings of the mesh along the y direction is performed through one of the utilities that can be found inside the folder `1-pre_processing/stretching_mesh`.

Channel flow

For a channel flow case, the default function of Incompact3d can be used, `stretching_parameter_channel.f90`.

Temporal turbulent boundary layer

For temporal TBLs simulations a new function was developed, starting from the stretching subroutine that can be found inside the original solver of Incompact3d. This new function is a Python script, `mesh_evaluation.py`. This function allows to estimate the mesh sizes and other relevant parameters by introducing the following inputs:

- Number of points: n_x,n_y,n_z.
- Domain dimensions: L_x,L_y,L_z.
- Stretching parameter: β.
- Kinematic viscosity: ν.
- Velocity of the wall: U_w.
- Time step: Δt.
- Tripping wire diameter: D.
- Skin friction coefficient at peak: $c_{f,max}$.
- BL thickness: δ.

And it produces the following outputs in `sim_settings.txt` file:

- Non-dimensional domain dimensions at IC and at peak c_f: L_x^+,L_y^+,L_z^+.
- CFL, Péclet, Numerical Fourier and stability parameter: Co, $\mathcal{D}$, $Pé$, S.
- Mesh size in y direction at the first element near the wall at IC, at peak c_f and at $Re_\tau = 500$: Δy_1^+.
- Mesh sizes in x and z directions at IC, at peak c_f and at $Re_\tau = 500$: Δx^+, Δz^+.
- Mesh size in y direction at the BL edge at $Re_\tau = 500$: Δy_δ^+.
- Number of mesh nodes `npvis` in the viscous sublayer at c_f peak.
- Number of mesh nodes `npsl` in the initial shear layer.
- Approximate initial shear layer momentum thickness θ_{sl}.
- Initial shear layer thickness δ_{99}^+.
- Shear velocity u_τ at IC, at peak c_f and at $Re_\tau = 500$.
- Total number of mesh points, n_{tot}.

In the file `mesh_y.txt` instead:

- Dimensional mesh spacings in y direction: Δy.
- Aspect Ratios (ARs) in the xy plane of grid elements (ratio width/height of a single element).
- Growth Rates (GRs) in the xy plane of grid elements (ratio of heights of adjacent elements).

It is worth noticing that in a temporal BL simulation, the peak c_f value constraints the height of the first cell at the wall Δy_1, as in standard CFD simulations. However, the decrease of c_f along the simulation (and thus the increase in viscous length δ_ν) imposes a constraint for the domain dimensions L_x, L_y, L_z since they appear progressively "smaller" (their non-dimensional counterparts decreases). Too low values of L_x^+,L_y^+,L_z^+ must be avoided in order to do not enforce a too strong periodicity in the turbulent structures at the wall.

For numerical stability, it is recommended to maintain $Co < 1$, $D < 0.5$, $Pé < 2$ and $S < 1$.

Final remarks

The Python function `mesh_evaluation.py` can handle also Channel flow simulation setups. The scaling employed by Incompact3d is based on the laminar Poiseuille flow. It is possible to estimate the related friction Reynolds number and the main quantities also calculated for the TTBL section (for more details on the reference scales for channels, see the *Quick Incompact3d guide*).

Pre-processing quantities

Calculated quantities for a temporal TBL in `mesh_evaluation_ttbl.py`.

Shear velocity at IC

$$\frac{\partial U}{\partial y} = -\frac{U_w}{4\theta_{sl}} \cdot \frac{1}{\cosh^2\left(\frac{D}{2\theta_{sl}}\right)}$$

$$u_\tau = \sqrt{\nu \left|\frac{\partial U}{\partial y}\right|}$$

Shear velocity at peak friction coefficient

$$u_\tau = U_w \sqrt{\frac{c_f}{2}}$$

Initial velocity profile

$$U_0^+(y) = \frac{U_w^+}{2} + \frac{U_w^+}{2} \tanh\left[\frac{D}{2\theta_{sl}}\left(1 - \frac{y}{D}\right)\right]$$

Initial shear layer momentum thickness

$$\theta_{sl} \approx \frac{54\nu}{U_w}$$

Initial Courant-Friedrichs-Lewy number (< 1)

$$Co = \frac{U_w \Delta t}{\Delta x}$$

Initial Numerical Fourier number (< 0.5)

$$\mathcal{D} = \frac{\nu \Delta t}{\Delta x^2}$$

Initial Péclet number (< 2)

$$Pé = \frac{U_w \Delta x}{\nu}$$

Initial stability parameter (< 1)

$$S = \frac{U_w^2 \Delta t}{2\nu}$$